Preliminary investigations of placer gold settings in Arch Creek, Kluane district, southwestern Yukon

K.E. Kennedy* and S. van Loon
Yukon Geological Survey

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ABSTRACT

Preliminary investigations of the glacial history, surficial geology and placer gold setting in Arch Creek, Kluane district, southwestern Yukon are focused on natural exposures and mining cuts to constrain stratigraphic relationships. Surficial deposits in the creek are primarily related to glacial advances from the Donjek valley, but are complicated by glaciation in the nearby Burwash Uplands and Shakwak Trench. While it is likely that bedrock sources of placer gold are being augmented by buried paleo placer deposits, mining to date has focused on modern channel deposits. Placer gold exploration targets in paleo-channel and glacial deposits are suggested.

* *kristen.kennedy@gov.yk.ca*

INTRODUCTION

Bound by the Donjek River to the west, the Duke River to the south, and the Alaska Highway to the north and east (Fig. 1), the study area is characterized by high mountains, deep valleys, and a broad upland plateau between the Donjek and Duke rivers called the Burwash Uplands. The Burwash Uplands are part of a larger physiographic region known as the Duke Depression, a complex of valleys and plateaus separating the Kluane Ranges from the Icefield Ranges to the west and extending from the Duke River north past the international border (Bostock, 1948; Rampton, 1981). Thought to be part of a former erosional surface (Rampton, 1981), bedrock is poorly exposed on the Burwash Uplands, and interpretations of both bedrock and surficial geology are hampered by a thick, unbroken blanket of glacial deposits overlying the plateau surface.

Placer production in the Kluane district has remained consistent for the past decade (YGS, 2010). In 2016, the district produced 1,287 ounces, making up 2% of Yukon's total, with the most significant contributions from Gladstone, Burwash, Rabbit, Ruby, Wade and Bliss creeks. Arch Creek, a west-flowing tributary to the Donjek River (Fig. 1), had one active mining operation in 2016 and generated 880 ounces of placer gold from 1959 to 2016. Placer claims cover nearly the entire length of the stream, however, no detailed surficial geological mapping has been undertaken in the area, and little progress has been made toward describing the stratigraphic setting of placer deposits in the district.

The Kluane district also has significant bedrock mineral potential, including several styles of mineralization, with exploration centered on nickel-copper-platinum group

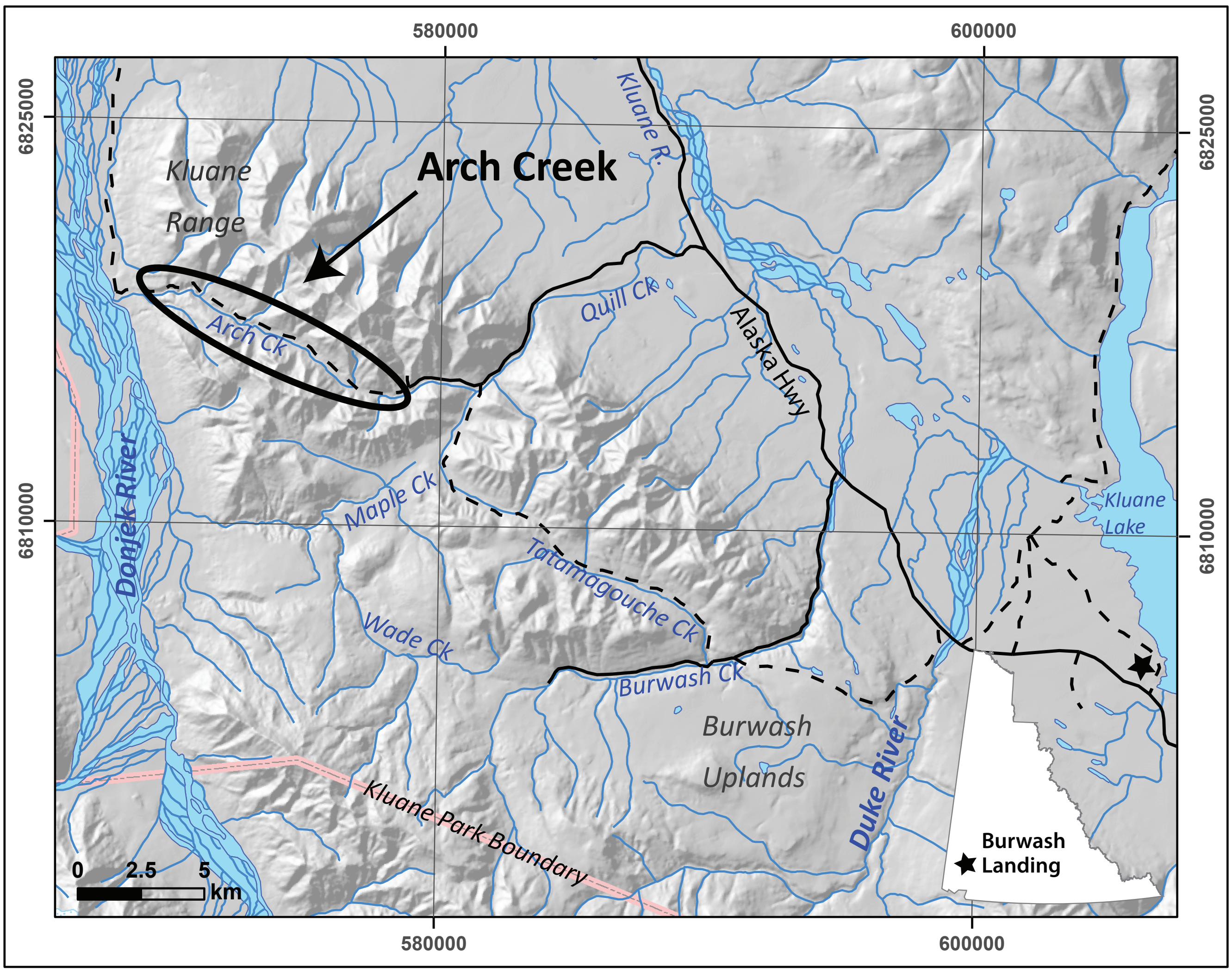

Figure 1. Location of Arch Creek, in the Kluane Range of the St. Elias Mountains, northeast of Burwash Landing (starred) and Kluane Lake. Major roads and highways are denoted by solid black lines and trails and secondary roads are denoted by dashed lines.

elements (PGE) associated with Triassic ultramafic rocks (Fig. 2; Israel *et al.*, 2006). Intrusion related mineralization (porphyry and skarn mineralization) has been shown to be associated with the Kluane Ranges suite throughout the area. Significant paleo-placer is also believed to be associated with the Oligocene Amphitheatre Formation. The Airways showing is a suggested source of gold for Arch Creek placer deposits (Fig. 2; YGS, 2010). Preliminary observations of Arch Creek are part of a larger, ongoing project to describe the surficial geology of the Burwash Uplands, as well as nearby streams in the Kluane mining district (Burwash, Quill, Maple, Wade and Tatamagouche).

GLACIAL HISTORY

North of Burwash Uplands, creeks draining the Kluane Ranges have undergone significant modification from

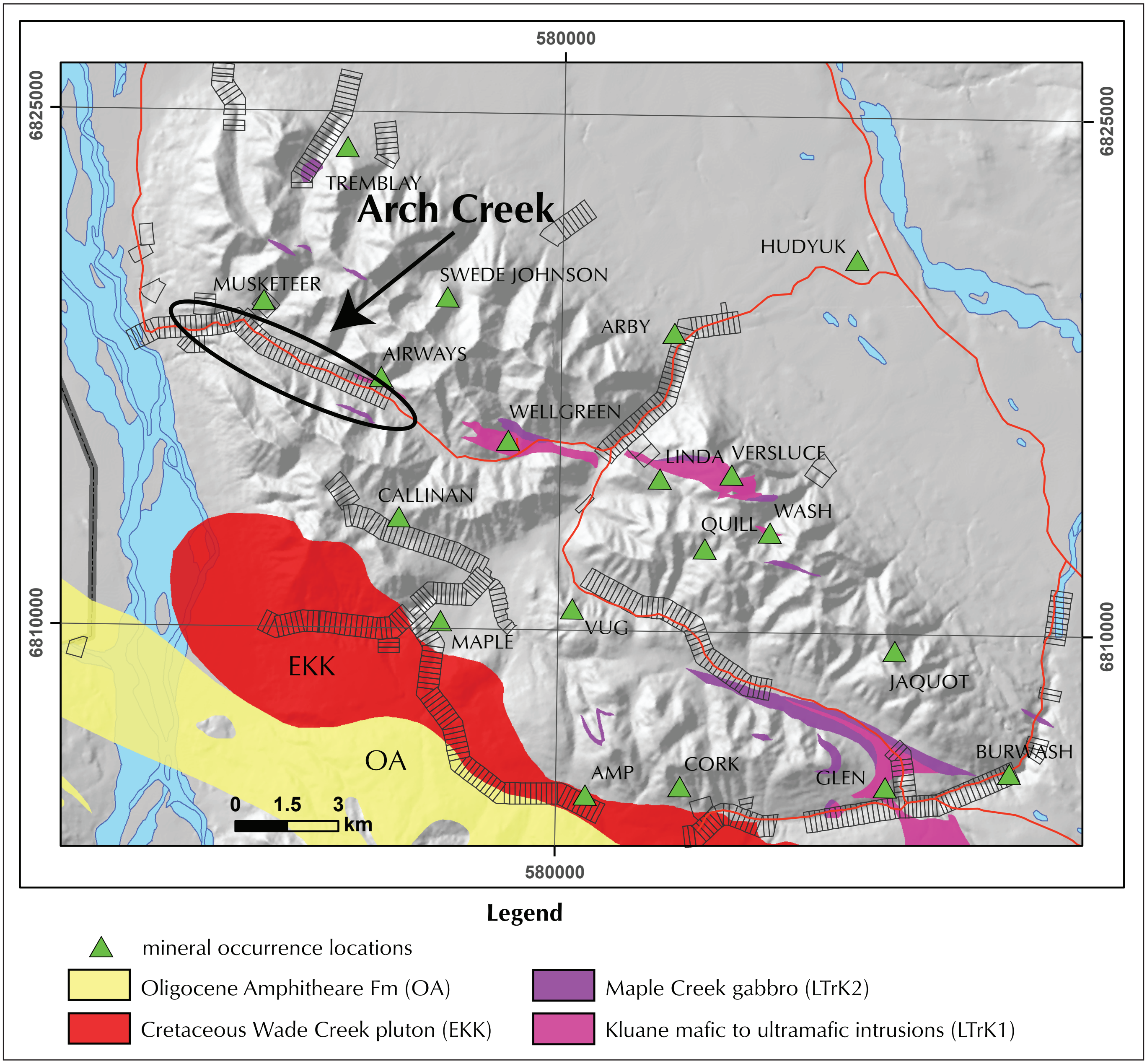

Figure 2. *Placer claims (aligned with creeks), mineral occurrence locations (triangles), and geologic units with high mineral potential (after Colpron, 2016) in the area surrounding Arch Creek. Triassic ultramafic rocks with potential to host PGE mineralization (LTrK1 and 2; pink and purple), Cretaceous igneous rocks with potential to host copper, molybdenum and gold mineralization (EKK; red), and Oligocene conglomerate rocks with potential to host paleo-placer deposits (OA; yellow) all occur upstream and up-ice from Arch Creek.*

glaciation and the rapid uplift of the Kluane Ranges, and are characterized by steep slopes and canyons which have been modified by mass wasting, stream erosion and glacial scouring. Located in the lee of the Icefields Range, these high peaks were likely too dry to generate substantial glaciers, and most of the high-elevation surfaces in this area remained ice-free during recent glacial advances from the south and west (Rampton, 1981). Some evidence exists for small alpine and cirque glaciers in tributary valleys to Arch Creek, but it is unlikely these advanced into the Arch Valley, and they may have become more limited in extent during the Pleistocene. Lower elevation surfaces, such as the Burwash Uplands and valley margins and floors, were affected by ice advances both from the Donjek Valley on the west and the Shakwak Valley on the east (Fig. 3). Advances of ice in both valleys would have flowed up tributaries of the Kluane Ranges, impounding creeks and redirecting flows over local drainage divides.

As ice in the Donjek and Shakwak valleys receded, some creeks were able to reoccupy their former valleys, while others were partially or entirely moved to new locations. These adjustments to stream locations are important for placer gold settings for two reasons: (1) former channels that are currently buried beneath glacial sediments likely contain economic placer deposits; and (2) the high stream energy required to incise streams into their new locations can concentrate placer gold into modern stream gravel.

The Quaternary (past ~2.65 million years) in southwest Yukon has been marked by cyclical advance and retreat of valley glaciers originating in the high St. Elias Mountains, which have, during extended cold periods, coalesced into large ice sheets that filled the broad Shakwak Trench and advanced up to 125 km to the north (Fig. 3; Duk-Rodkin, 1999). At maximum extent, the St. Elias lobe of the Cordilleran Ice Sheet likely remained somewhat

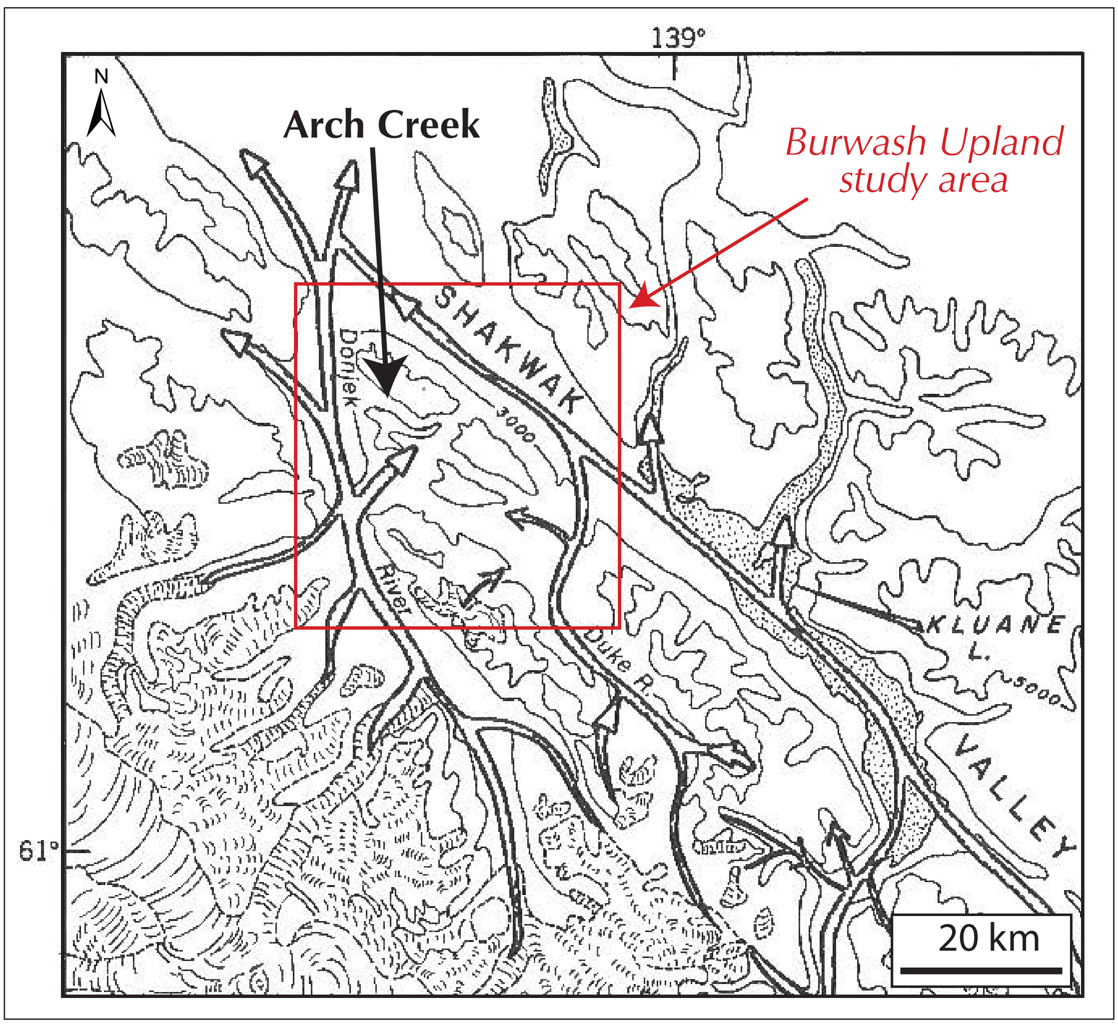

Figure 3. *Regional northwesterly ice flow in the study area (note arrows) at glacial maximum. Modified from Rampton, 1979.*

independent and valley-constrained, but is thought to have followed similar ice configurations through many glacial and interglacial periods (Duk-Rodkin, 1999). While most landforms and sediments preserved today are the result of the most recent period of glacial advance (~15-20,000 years ago), evidence of previous glaciations exists in some deep valleys that preserve a much older Quaternary history. At Silver Creek, a tributary to Kluane Lake at the south end, Turner *et al.* (2016) identified at least five Middle to Late Pleistocene advances of the northern Cordilleran Ice Sheet. The three most recent advances identified at Silver Creek correlate well with glacial deposits identified in the nearby Snag-Klutlan area (Rampton, 1971), as well as with records from central and southern Yukon (Turner *et al.*, 2013; Westgate *et al.*, 2008; Ward *et al.*, 2007; Ward *et al.*, 2008).

Surficial geological mapping has been completed at a scale of 1:100 000 for part of the study area (Rampton, 1980), but no surficial maps exist for Arch, Maple and Wade creeks or their surrounding uplands. Regional surficial geological mapping for the Alaska Highway corridor (Rampton, 1979, 1980) and Kluane National Park (Rampton, 1981) show glacial limits in Burwash, Tatamagouche and Quill creeks mapped to elevations of ~1200-1400 m above sea level (a.s.l.). Preliminary mapping at Arch Creek suggests that there were incursions of ice into the western uplands which resulted in glacial limits of a similar scale and elevation as observed on the eastern flank, adjacent to Shakwak valley glaciers. Alpine glacial limits are not mapped in this region of the Kluane Ranges, but north-facing cirques likely supported small glaciers during the last glacial period which would have driven high rates of erosion in the mountains and supplied glacial materials and meltwater to the Arch Creek valley.

ARCH CREEK PLACER MINING

Russel Nelson has been placer mining on Arch Creek since 2010, mining modern creek and terrace gravel above the second (uppermost) canyon (Fig. 4). In 2016, the mining cut ranged from 5 to 15 m in height and was ~60 m wide. Pay consisted of three distinct units (Fig. 5): Unit 1 is a boulder-rich, angular, pebble-cobble gravel overlying bedrock and has a thickness of up to 0.5 m; Unit 2 is a 1 m-thick, pebble gravel with a fine-grained sand to silty matrix and has weak planar, downstream-dipping stratification; and Unit 3 is a coarse, angular, pebble-cobble-boulder gravel with a coarse sandy matrix and has a thickness of up to 1.6 m in the exposed mining cut. Unit 3 appears to have a weakly formed boulder lag deposit in the lower ~50 cm of the unit, and Unit 2 is

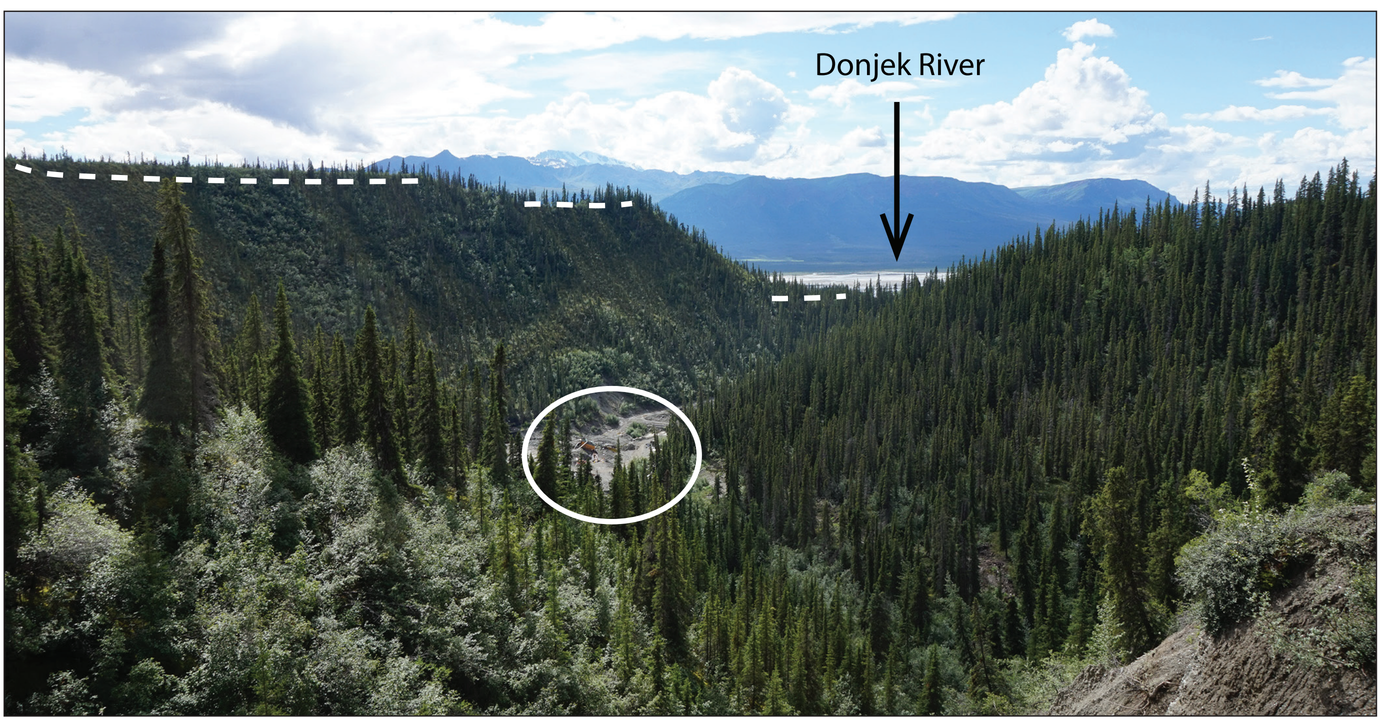

Figure 4. *View to the west, or downstream, on Arch Creek toward the Donjek River; Russel Nelson's 2016 mining cut is denoted by a circle in the middle ground. The mine is located immediately above the second canyon at the downstream end of a bedrock drop on Arch Creek. Three left-limit terraces are visible high above the creek (dashed white lines).*

Figure 5. *Stratigraphy of a right-limit cut at Russel Nelson's Arch Creek placer mine in 2016. Unit 3 in photo is approximately 1.5 m thick.*

reported to be moderately cemented. The pay package is overlain by up to 5 m of colluvial slope materials that blanket the margins of the creek and cover low terraces on both the right and left limits. Gold recovered in Arch Creek has an average fineness of 870, comprising ~80% coarse gold and 20% fine and flour gold. Gold grain character ranges from polished and bright, to rough and angular. Copper, platinum and silver nuggets have also been recovered in Arch Creek.

ARCH CREEK STRATIGRAPHY

Three sections were examined in 2016 along Arch Creek from below the drainage divide to just above the canyon (Sites 2, 3 and 4 on Fig. 6). Sites 2 and 3 are comprised of fluvial, lacustrine and glacial deposits, whereas the highest upstream section (Site 4) is comprised of only fluvial and/or glaciofluvial materials (Fig. 7). The stratigraphy from the most complete section (Site 2) is presented (Fig. 8). The section exposes sediments deposited in two terrace landforms on the right limit (north side) of the creek. The creek adjacent to the section has been mined successfully.

Unit 1: Openwork pebble gravel containing ~30% medium pebbles, ~60% small pebbles and ~10% sandy matrix. This unit is poorly exposed, with ~2 m exposed above the Arch Creek road.

Unit 2: This unit is composed of 75 cm of tan-coloured, finely laminated silt, sand and clay that is largely impermeable to groundwater and forms an aquitard to water draining through sediments in the section (Fig. 9). Unit 2 overlies Unit 1 with a sharp, conformable contact characterized by silt drapes on underlying pebbles. Fining-up beds of ~1 cm thickness comprise rust stained sand, tan silt and thin laminations of clay. Beds are planar to wavy and include a 20 cm-thick zone of soft sediment deformation visible over a lateral width of ~2 m which is associated with rare, pebble sized clasts. Ripple cross laminations occur in the upper 10-15 cm of the unit and appear to be prograding downstream (Fig. 10). No other evidence of flow direction was observed.

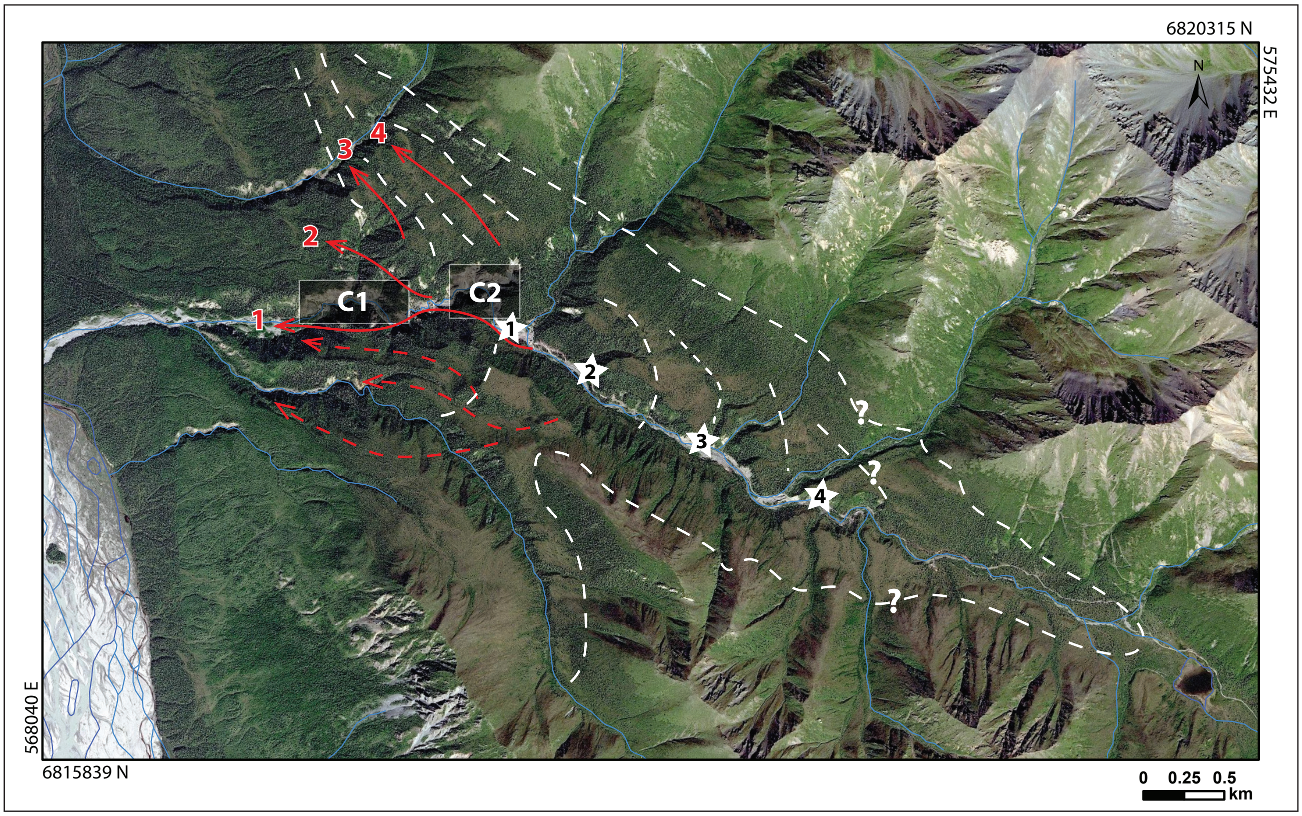

Figure 6. *Location of mining operation (1) and stratigraphic sections (2, 3 and 4) on Arch Creek. The lower (C1) and upper (C2) canyons on Arch Creek are outlined with boxes. Dashed white lines are possible maximum and recessional glacial limits, and red arrows indicate possible paleochannel locations. Flow on Arch Creek is to the left side of the image.*

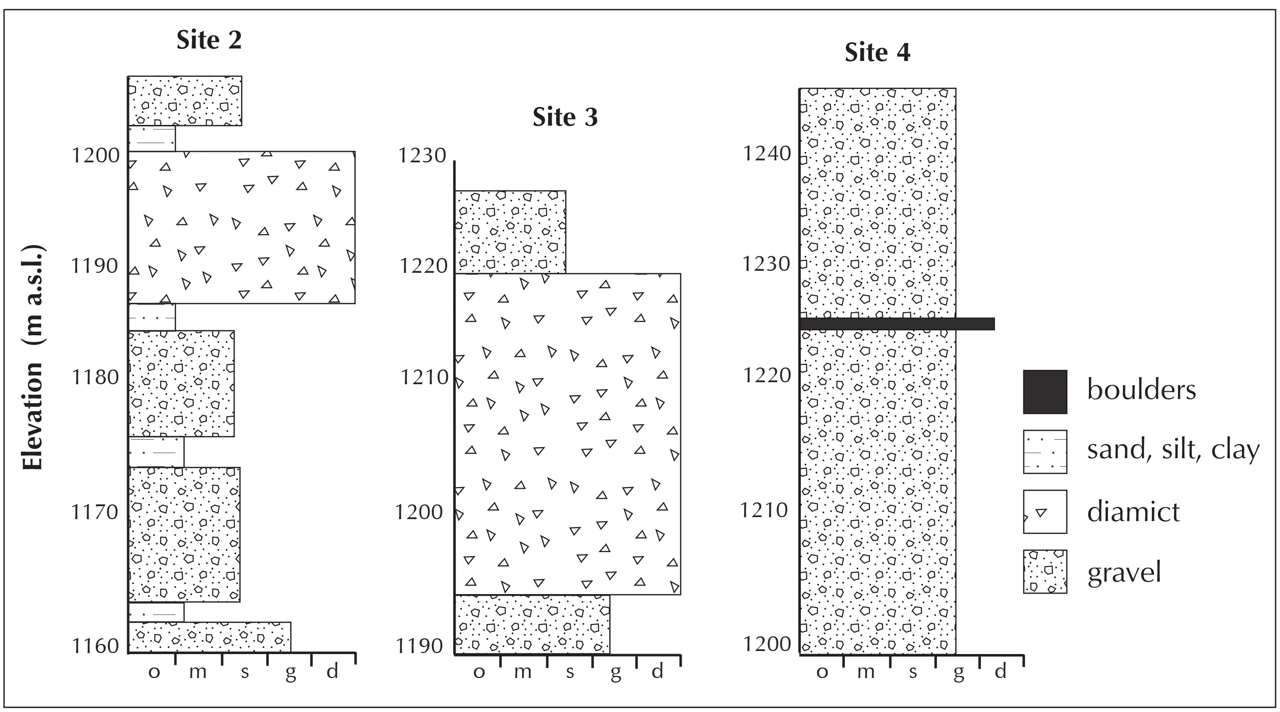

Figure 7. *Stratigraphic sections examined at Sites 2, 3 and 4 on Arch Creek. Stratigraphy is generalized and organized by grain size (o=organic; m=mud; s=sand; g=gravel; and d=diamict/boulders).*

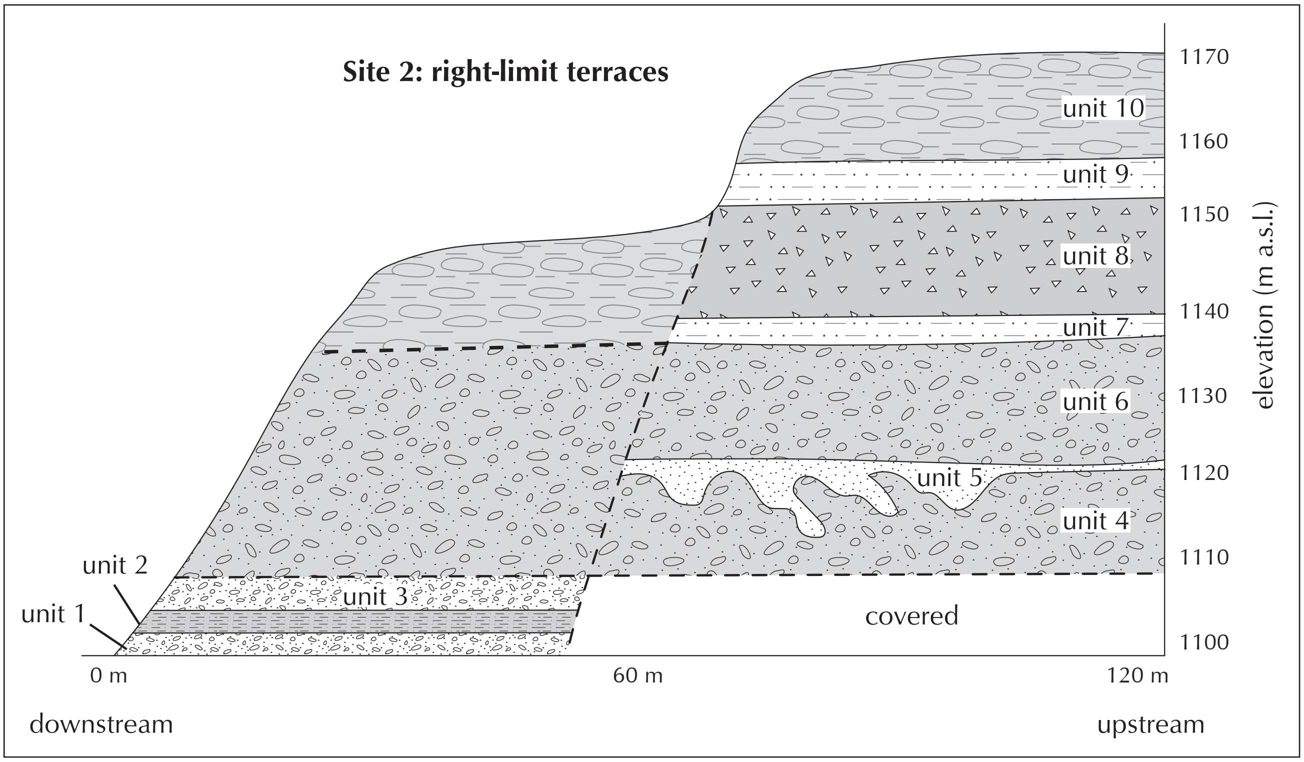

Figure 8. *Profile of right-limit terraces at Site 2 on Arch Creek. Material textures are described in text. Dashed lines indicate assumed contacts and solid lines indicate observed contacts.*

Figure 9. *Units 1-3 at Site 2 on Arch Creek. Unit 2 is a flat-lying silt, sand and clay unit deposited conformably over the underlying gravel of Unit 1.*

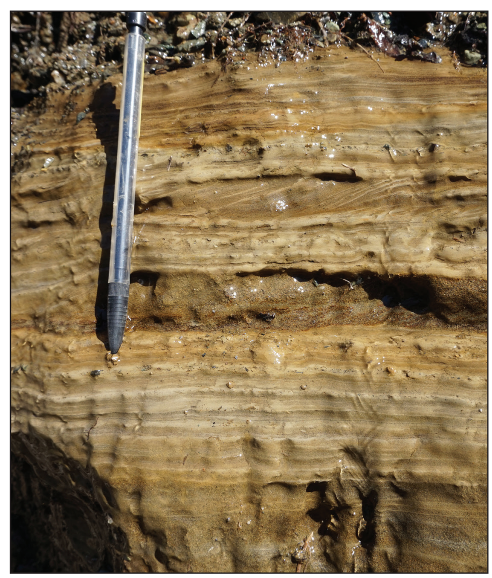

Figure 10. *Current ripples in fine sand, silt and clay of Unit 2 at Site 2 on Arch Creek. Downstream is to the left of the photo.*

Unit 3: Pebble gravel with a matrix comprising ~50% coarse sand to small pebbles. Clasts are predominantly pebble sized and coarsen upward to include rare cobbles. Gravel textures are obscured by high volumes of water draining through this unit, and fine components of the matrix may have been removed by surface and subsurface water.

Unit 4: Subround to angular pebble-cobble gravel with 40-60% matrix comprising coarse sand (40%), medium to fine sand (40%) and silt (~20%). Weak planar horizontal bedding and imbrication is present and oriented downstream (west).

Unit 5: Sediments of this unit are truncated and deformed, massive to laminated, tan, medium to fine sand (Fig. 11). Bedding and laminations up to 30 cm thick with silt outlining ripple bedforms suggest lateral accretion toward the centre of valley. Individual sand units are continuous over a few metres before pinching out.

Unit 6: Subround to angular pebble-cobble gravel with 40-60% matrix comprising coarse sand (40%), medium to fine sand (40%) and silt (~20%). Weak planar horizontal bedding and imbrication is present and oriented downstream (Fig. 12). Erosive sub-planar contacts with underlying sand (Unit 5) where present.

Unit 7: Fining-up sequence (~50 cm thick) of brown silt to grey silty clay overlying a 2 cm-thick oxidized zone at the top of Unit 6.

Unit 8: Clay-rich, grey diamict with 40-50% clayey to silty matrix and 50-60% rounded to angular pebble-cobble-boulder clasts (Fig. 13). Sand layers are throughout the unit, have an average thickness of ~5 cm, and are oxidized to a brown colour. Clast sizes coarsen upward from pebble to cobble.

Unit 9: Alternating ~30 cm-thick beds of sand and sandy silt compose this unit which is ~5 m thick. Gradational boundaries exist between coarser and finer beds and exhibit minor deformation of finer beds at lower contacts.

Unit 10: This uppermost unit consists of a ~10 m-thick, washed, pebble-cobble gravel with subround to angular clasts in a sandy matrix.

Figure 11. *Distorted contacts between sand in Unit 5 and underlying gravel in Unit 4 are outlined with dashed white lines. Unit 6 has an erosive lower contact with Unit 5.*

ARCH CREEK GLACIAL HISTORY

At Site 2, sediments are made up of predominantly glaciofluvial gravel interbedded with thin glaciolacustrine deposits and one till unit. This sequence is interpreted to represent at least one, and possibly two glaciations from the Donjek valley up the Arch Creek valley.

Glacial advances upstream on Arch Creek extended at least as far as Site 3, and possibly as far as the modern divide between Arch Creek and the east-flowing Nickel Creek, a tributary to Quill Creek (small lake on Fig. 6). The most recent advance, and possibly earlier advances, were not highly erosive and preserved pre-existing valley fill. While short-lived impoundment of the drainage is recorded by glaciolacustrine sediments deposited as the

Figure 12. *Crude planar bedding visible in Unit 6 at Site 2 on Arch Creek. A similar gravel unit was observed at sites 3 and 4.*

glacier advanced up-valley, meltwater appears to have been able to drain relatively freely to the east during the maximum extent of glaciation in Arch Creek. This suggests Quill Creek was ice-free when Arch Creek was glaciated, and that the glacier in the Donjek Valley advanced past Arch Creek prior to Shakwak ice (a separate lobe to the east) reaching Quill Creek.

As the glacier in Arch Creek began to retreat back toward the Donjek Valley, glaciofluvial meltwater was diverted westward again, and at least partially impounded against the retreating ice front. Meltwater flowing across upper Maple and Tatamagouche creeks into the Quill Creek valley may also have been diverted into Arch Creek by ice in the Shakwak valley at this time (Rampton, 1981). Recession of the glacier in Arch Creek valley is marked by thick deposits of glaciofluvial gravel. Some of these deposits may be coincident with sediment input from large tributaries (*i.e.*, Site 4 on Fig. 6) which may have supported alpine glaciers at glacial maximum. Both glacial and periglacial processes in alpine tributaries would have transported significant local bedrock material to the Arch Creek valley which was, at least in part, reworked by modern or interglacial streams.

Recessional ice limits (dashed white lines on Fig. 6) in Arch Creek valley are better preserved on the north (right-limit) side of the valley, suggesting meltwater drained north out of Arch Creek, following the probable slope of the ice surface in the Donjek Valley. The modern channel of Arch Creek in both the lower and upper canyons (C1 and C2 on Fig.6) is off-set to the north, roughly following glacial limits, and its current location may have emerged as an ice-marginal meltwater channel while the valley was still occupied by ice. Successive levels of glaciofluvial terraces on both sides of the Arch Creek valley above the canyons likely record on-going, post-glacial incision of Arch Creek toward the Donjek River, or alternatively, step-wise retreat of the ice front in, and adjacent to, the Arch Creek valley. Higher terraces, and those closer to the valley margins, contain remnant valley fill (till, glacial lake sediments), whereas lower terraces closer to the middle of the valley are comprised of reworked glacial and fluvial materials from the adjacent slopes.

Figure 13. *Unit 8 at Site 2 is a compact glacial diamict with a clay-silt-sand matrix. Shovel handle is 5 cm wide.*

PLACER POTENTIAL IN ARCH CREEK

Arch Creek valley is a deep, steep-sided trough that has been filled by thick glacial deposits and subsequently reworked by post-glacial streams repeatedly in the past. While the general orientation of the channel in the valley has not altered significantly, the specific location of the stream channel has changed in at least two locations (where the modern stream is currently incised into bedrock canyons), and it is possible the stream may have occupied many different channels along its length during the Quaternary. Historic and modern mining have largely been focused within, or directly above and below the upper and lower canyons, but there is potential for economic deposits associated with paleochannels outside the modern stream channel and above the upper canyon.

Reger and Bundtzen (1990) identify a number of potential exploration targets in glaciated terrain based on their work on Valdez Creek, a stream with similar geography and glacial history to Arch Creek. Potential targets include: (1) buried paleochannels; (2) buried fans downstream of paleochannels; (3) former ice-marginal meltwater streams that reworked gold-bearing, valley-side colluvium and till; and (4) zones where gold-bearing moraines were breached and reworked by late-glacial and postglacial streams. Buried paleochannels of interglacial deposits on Arch Creek are the most prospective target for this valley, followed by former ice-marginal meltwater streams.

The presence of angular gold in Arch Creek suggests at least part of the placer deposit is sourced within the drainage, and the gold may have been mobilized by alpine glaciation. Gold carried by glacial streams could be preserved in higher elevation meltwater channels (*i.e.*, channels at sites 3 and 4 on Fig. 6), or reworked by tributary streams that cross these channels, such as the right-limit tributary above the upper canyon (above Site 1 on Fig. 6). Alternatively, gold mobilized by glaciation can be reworked into the valley bottom and carried in the modern stream, or any previous paleochannels of Arch Creek that existed during interglacial periods. These valley-bottom paleochannels are more likely to represent longer periods of placer concentration and may have been reoccupied during successive interglacials.

Beginning approximately one kilometre upstream of the upper canyon (near Site 2 on Fig. 6), Arch Creek has been diverted slightly to the north, probably by north-flowing ice from the Donjek Valley. The Arch Creek valley also broadens at this point, and paleochannels may exist in a number of locations both south and north of the modern stream (Fig. 6). The most probable paleochannel locations of Arch Creek are indicated by the numbered red dashed arrows one and two on Figure 6. These locations either closely follow the orientation of upper Arch Creek valley (2), or the modern alignment of Arch Creek (1). Both suggested paleochannels occupy a narrow space between the lower (C1) and upper (C2) canyons that may represent a former paleochannel of Arch Creek, or a deep, lateral meltwater channel along the Donjek valley. The two southernmost channels are also a possibility, however, early mining efforts in the area would probably have identified these since they are dissected by the lower left-limit tributary to Arch Creek (*see* red dashed arrows south of paleochannels 1 and 2 in Fig. 6), and would result in a near-surface enrichment in this tributary if present.

Finally, paleochannels of tributary streams to Arch Creek may also be prospective if bedrock sources of gold are located upstream. The former courses of tributary streams may be off-set from their modern course and/or buried under valley-side glacial deposits. In addition, alpine till deposits on bedrock should also be evaluated near the mouths of the tributary valleys. Alpine glaciers with limited extent may have reworked placer gold-enriched fluvial deposits as they flowed toward the main valley of Arch Creek. On-going placer exploration in Arch Creek would benefit from a program of geological mapping, prospecting, geophysics and drilling (preferably cased holes) to help define paleochannel locations.

CONCLUSION

Arch Creek has likely been glaciated at least twice during the Pleistocene by ice flowing up-valley from the Donjek Glacier. Locally sourced ice was limited to alpine glaciers in tributary valleys, however, Shakwak Valley ice from the east in Quill, Tatamagouche and Maple creeks likely complicated drainage and sedimentation in Arch Creek valley. At sections examined above the canyons on Arch Creek, Donjek glaciation was only weakly erosive, and older deposits are preserved beneath glacial materials. Since the last glacial maximum, deep incision of Arch Creek has reworked both glacial and interglacial materials into the modern creek, and left thick terrace and fan deposits on valley sides.

It is likely that paleochannels are present in Arch Creek valley, but may be obscured by thick deposits of glacial materials. Exploration on the creek should focus on areas where known or potential paleochannels intersect with the modern channel or side gullies where there may have been incision to bedrock, or close to bedrock. Paleochannels are more likely to be present in lower Arch Creek where the valley is broad, but it is also possible to have deeply buried paleochannels further upstream along the valley margins.

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